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Demystifying NAPL Science for the Remediation Manager

Discharge vs. Drawdown (DvD) Graphs

Graphical Analysis of Unconfined LNAPL Baildown Test Data

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Efficient LNAPL remediation design is dependent upon reliable predictions of LNAPL production, which in turn may be dependent upon calculated LNAPL transmissivity distributions for a site. Accurate LNAPL transmissivity calculations from baildown tests require accurate drawdown measurement and interpretation. In this issue we will focus on DvD Graphs diagnostic of unconfined LNAPL conditions.

BACKGROUND: Discharge versus Drawdown (DvD) Graphs are used in conjunction with LNAPL baildown tests to graphically confirm ideal unconfined LNAPL discharge conditions. The theory behind measurement of LNAPL transmissivity (T_n) via baildown testing is similar to the theory behind aquifer slug testing. Bouwer and Rice (1976) showed that under ideal conditions discharge during a slug test is directly proportional to drawdown.

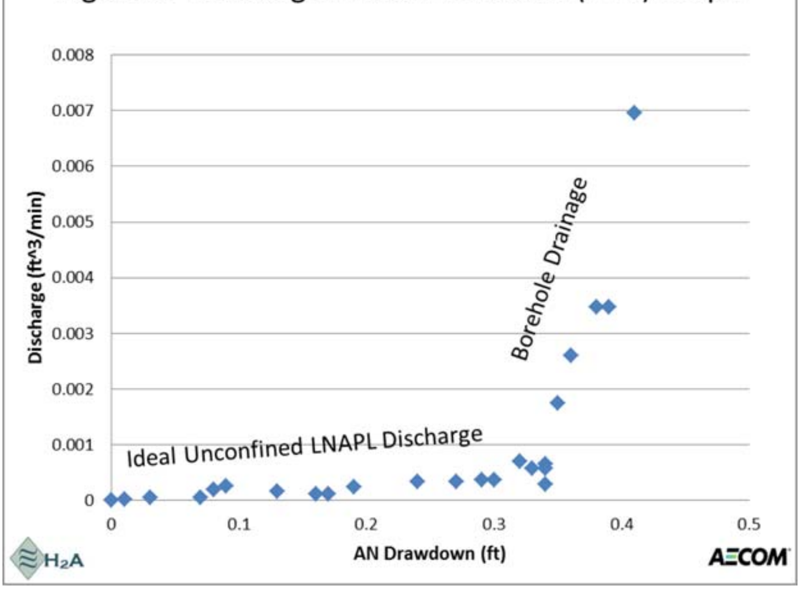
DEFINITION: A Discharge versus Drawdown (DvD) Graph is a scatter plot of LNAPL recharge into a well (recharge into a well includes any initial filter pack drainage and the discharge from the formation) during a baildown test versus the LNAPL drawdown. Typically LNAPL drawdown is calculated as either 1) change in air/NAPL (AN) interface or 2) change in apparent NAPL thickness (ANT) times the quantity one minus the LNAPL specific gravity. Both methods assume unconfined conditions, but the ANT method also assumes a constant potentiometric surface.

Discharge may occur from the well filter pack and/or from one or more lithologic intervals of mobile LNAPL. Under ideal subsurface fluid flow conditions, discharge is directly proportional to drawdown. Therefore, a DvD graph of ideal unconfined LNAPL response should exhibit a constant rate of change (constant slope or straight line).

INTERPRETATION: Ideally, both discharge and drawdown will approach zero simultaneously as LNAPL and groundwater recharge approach equilibrium conditions. Failure of both values to approach zero together may indicate a non-equilibrium initial (pre-test) LNAPL elevation, which can lead to substantial error in LNAPL transmissivity values calculated from such baildown tests.

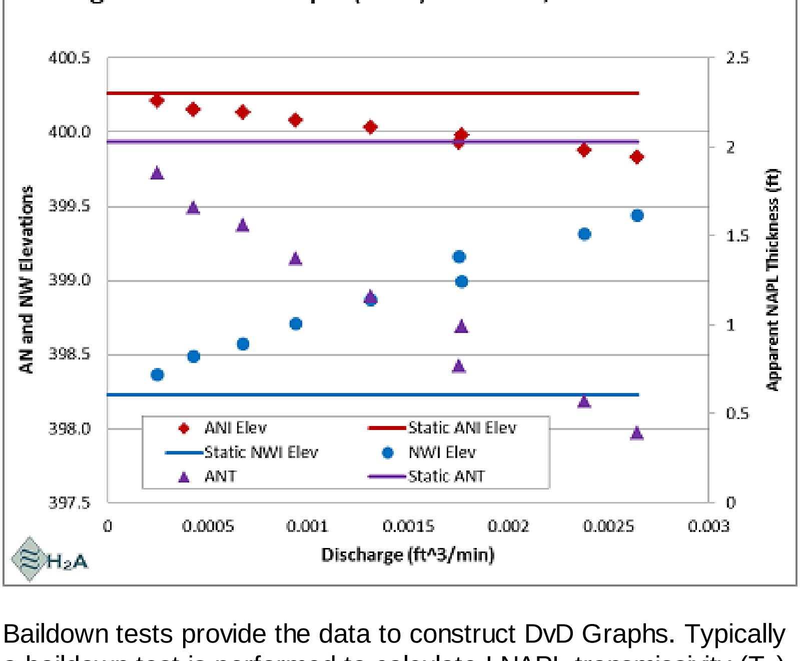
Frequently the early data from a baildown test is representative of filter pack drainage rather than formation discharge. Filter pack drainage in Figure 1 can be recognized as an initially steeper discharge versus drawdown relationship (higher rate of change in discharge per unit drawdown). This is similar to the double straight line effect observed from slug tests analyzed with the Bouwer-Rice method for wells screened across the water-table.

Figure 1: Discharge versus Drawdown (DvD) Graph



DvD Graphs can also be constructed with drawdown expressed as an elevation on the vertical axis and discharge on the horizontal axis. Figure 2 shows an elevation-based DvD graph that incorporates static and recharge AN and NW interface elevations as well as ANT recharge versus LNAPL drawdown. The DvD Graph may then be evaluated against elevation-based boring logs or cross-sections, or used to create an advanced Hydrostratigraph for the well. Discharge trends may be matched directly to lithologic zones and LNAPL interface and thickness trends on the Hydrostratigraph.

Figure 2: DvD Graph (elev) with AN, NW and ANT



Baildown tests provide the data to construct DvD Graphs. Typically a baildown test is performed to calculate LNAPL transmissivity (T_n) values from individual wells. However, under non-ideal LNAPL conditions, ANT in wells may be exaggerated and drawdown values used to calculate T_n may require correction so they do not exceed the mobile LNAPL interval in the formation (interval from which LNAPL is discharging into the well). DvD Graphs can be used to estimate the mobile LNAPL interval, which, when multiplied by the quantity of one minus the LNAPL specific gravity, provides a correcting maximum drawdown value for T_n calculations. For example, the linearity of the recharge AN and NW interface elevations and ANT in Figure 2 all suggest unconfined essentially homogeneous LNAPL conditions and a mobile LNAPL interval in the formation approximately equal to the static ANT.

SUMMARY: DvD graphs may be used to identify unconfined intervals of LNAPL flow, which in turn represent the formation mobile LNAPL interval. When adjusted for the LNAPL specific gravity, this interval represents the maximum drawdown that could be attained in the LNAPL in the formation (assuming no applied vacuum or water drawdown), thereby providing a correcting limit for LNAPL drawdown for baildown tests.

DvD graphs are therefore valuable LNAPL Conceptual Site Model (CSM) tools to identify 1) lithologic zones of mobile LNAPL, 2) the formation mobile LNAPL interval, and 3) the maximum attainable LNAPL drawdown. These improved drawdown values allow calculation of T_n values that are more representative of formation LNAPL saturation and discharge conditions, which can in turn lead to more accurate LNAPL mobility and recoverability evaluations (more efficient remediation design).

REAL WORLD LIMITATIONS: A word of caution – real-world heterogeneities and other naturally-occurring or man-made groundwater fluctuations and other complexities may obscure the ideal discharge versus drawdown trends. In addition, an improperly or inaccurately conducted baildown test may not conform to the ideal trends. Improved data collection techniques, such as increased gauging frequency (e.g., gauge wells every 0.1 feet of recovered LNAPL thickness or less) and gauging until the well completely recovers, will provide improved DvD graphs for analysis. Multiple lines of evidence should be used.

Next month we will explore the causes and conditions for confined LNAPL.

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Introduction

Applied NAPL Science Review (ANSR) is a scientific ejournal that provides insight into the science behind the characterization and remediation of Non-Aqueous Phase Liquids (NAPLs) using plain English. We welcome feedback, suggestions for future topics, questions, and recommended links to NAPL resources. All submittals should be sent to Mike Hawthorne. If you know someone who is interested in NAPL science, please forward this issue to them using the "Forward" link at the bottom of the page.

Context

Volume 1 (2011) of *Applied NAPL Science Review* (ANSR) is focused on tools and scientific concepts to improve NAPL conceptual site models (CSM). An accurate, detailed CSM will cost-effectively guide risk evaluations, remedial action determinations, technology selection, remedial design, and end point attainment (closure) evaluations.

Terminology conventions:

AN: Air/NAPL interface (previously AOI)

NW: NAPL/Water interface (previously OWI)

CGWS: Corrected Ground Water Surface (No Change)

ANT: Apparent NAPL Thickness (No Change)

FNT: Formation NAPL Thickness (No Change)

Announcements

LNAPL Site Management Strategies Session (multiple platform presentations). June 27-30, 2011, Reno, Nevada. Bioremediation and Sustainable Environmental Technologies, BATTELLE. Click Here for link to conference web page.

Coming Up

The next newsletter will discuss causes and conditions for confined LNAPL.

Related Links

API LNAPL Resources

ASTM LCSM Guide

Env Canada Oil Properties DB

EPA NAPL Guidance

ITRC LNAPL Resources

ITRC DNAPL Documents

RTDF NAPL Training

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